CHAPTER 6

ENZYMES

MULTIPLE CHOICE QUESTIONS

1. **When the term enzyme was used first time?**
   (a) 1874 (b) 1876 (c) 1878 (d) 1880
2. **Who first time used the term enzyme?**
   (a) Winhelm Kuhne (b) Daniel Koshland (c) Emil Fischer (d) Darwin
3. **If organic cofactors are loosely attached with enzyme, they are called:**
   (a) Coenzymes (b) Prosthetic groups (c) Both a & b (d) None of these
4. **If organic cofactors are tightly bound to enzyme, they are called:**
   (a) Coenzymes (b) Prosthetic groups (c) Both a & b (d) None of these
5. **Which one is an organic cofactor?**
   (a) Zinc (b) Calcium (c) Iron (d) Flavin
6. **Which are coenzymes?**
   (a) Riboflavin (b) Thiamine (c) Folic acid (d) All of these
7. **The catalytic region of enzyme is called:**
   (a) Cofactor (b) Coenzyme (c) Prosthetic group (d) Active site
8. **Which enzymes are used for the removal of protein stains from clothes?**
   (a) Proteases (b) Amylases (c) Lipases (d) None pf these
9. **Which enzymes are used in dish washing to remove resistant starch residues?**
   (a) Proteases (b) Amylases (c) Lipases (d) None of these
10. **Who proposed lock and key model?**
    (a) Winhelm Kuhne (b) Daniel Koshland (c) Emil Fischer (d) Darwin
11. **Who proposed induced fit model?**
    (a) Winhelm Kuhne (b)Leeuwenhoek (c) Emil Fischer (d) Daniel Koshland
12. **When was lock and key model proposed?**
    (a) 1894 (b) 1896 (c) 1898 (d) 1890
13. **When was induced fit model proposed?**
    (a) 1952 (b) !954 (c) 1956 (d) 1958
14. **Number of discovered enzymes so far:**
    (a) 1000 (b) 1500 (c) 2000 (d) 2500
15. **The enzymes that act on lipids:**
    (a) Proteases (b) Lipases (c) Amylases (d) Pepsin
16. **The peptide bonds are broken by:**
    (a) Proteases (b) Lipases (c) Amylases (d) None of these

ANSWERS:

1	c	2	a	3	a	4	b	5	d
6	d	7	d	8	a	9	b	10	c
11	d	12	a	13	d	14	c	15	b
16	a								

SHORT QUESTIONS

Q. No. 1 Who first gave the concept of metabolism?

CONCEPT OF METABOLISM

The concept of metabolism was first of all given by Ibn-e-Nafees, who stated that:

'The body and its parts are always undergoing change.'

Meaning:

The term 'Metabolism' is derived from a Greek word meaning 'change'.

Q. No. 2 What is metabolism?

METABOLISM

Definition:

A set of biochemical reactions that occur in living organisms in order to maintain life is called metabolism.

Importance:

These processes allow organisms to:

- Grow
- Reproduce
- Maintain their structures
- Respond to their environments

Q. No. 3 What is the difference between anabolism and catabolism?

DIFFERENCE BETWEEN ANABOLISM AND CATABOLISM

Anabolism	Catabolism
Definition: The process in which larger molecules are synthesized through biochemical reactions is called anabolism.	**Definition:** The process in which larger molecules are broken down into simpler ones through biochemical reactions is called catabolism.
Energy: Energy is utilized in anabolism.	**Energy:** Usually energy is released in catabolism.
Example: Photosynthesis	**Example:** Respiration

Q. No. 4 Why enzymes are crucial to metabolism?

NECESSITY OF ENZYMES FOR METABOLISM

Enzymes are crucial to metabolism because they act as biocatalysts, and speed up and regulate metabolic pathways. During metabolism, chemicals are transformed from one form to the other by enzymes.

Q. No. 5 What is the difference between substrates and products?

DIFFERENCE BETWEEN SUBSTRATES AND PRODUCTS

SUBSTRATES	PRODUCTS
The molecules at which enzymes act are called substrates.	Enzymes act upon substrates and convert them into different molecules, called products.

Q. No. 6 Define activation energy.

ACTIVATION ENERGY

The minimum amount of energy required to start a biochemical reaction is called activation energy.

- All chemical reactions require activation energy

Q. No. 7 In what ways the enzymes lower the activation energy?

WAYS OF LOWERING ACTIVATION ENERGY

Enzymes lower the activation energy in several ways:

- They may alter the shape of substrate and reduce the requirement of energy for this change.
- Some enzymes do so by disrupting the charge distribution on substrates.
- Enzymes also lower activation energy by bringing substrate in correct orientation to react.

Q. No. 8 What are the two types of enzymes?

TYPES OF ENZYMES

Enzymes can be categorized on the basis of the site where they work. i.e. they may be:

i. **Intracellular Enzymes** e.g. Enzymes of Glycolysis working in cytoplasm.
ii. **Extracellular Enzymes** e.g. Enzyme Pepsin working in the stomach cavity.

Q. No. 9 Who first discovered the enzymes?

DISCOVERY OF ENZYMES

In 1878, German Physiologist Winhelm Kuhne first used the term Enzyme.

Q. No. 10 Are all biochemical catalysts proteins?

NATURE OF BIOCATALYSTS

All biochemical catalysts are not proteins, for example some RNA molecules also catalyze some reactions.

Q. No. 11 1. All enzymes are catalysts, 2. All catalysts are enzymes. Which one is correct?

Statement 1: All enzymes are catalysts

Q. No. 12 What are enzymes?

ENZYMES

Enzymes are proteins that catalyze (i.e. speed up) biochemical reactions and are not changed during the reaction.

Q. No. 13 Birds have higher body temperature than mammals. What would happen to the activity of a bird's enzyme if it is given the temperature of 37°C?

Reaction rate will slow down.

LONG QUESTIONS

Q. No. 1 Write a note on activation energy.

ACTIVATION ENERGY

Definition:

The minimum amount of energy required to start the biochemical reaction is called activation energy.

Need:

The need for activation energy acts as a barrier to the beginning of reaction. Enzymes lower such barriers by decreasing the requirement of activation energy.

Lowering of Activation Energy:

Enzymes lower the activation energy in several ways:

- They may alter the shape of substrate and reduce the requirement of energy for this change.
- Some enzymes do so by disrupting the charge distribution on substrates.
- Enzymes also lower activation energy by bringing substrate in correct orientation to react.

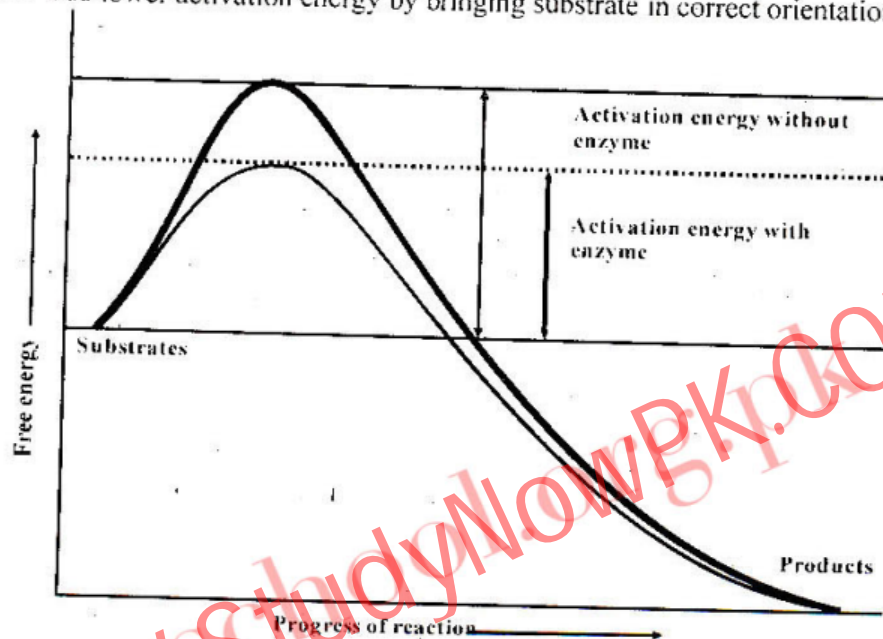



Figure: Enzymes Lower the Activation Energy

Q. No. 2 Describe the characteristics of enzymes.

Introduction:

In 1878, German Physiologist Winhelm Kuhne first used the term Enzyme.

CHARACTERISTICS OF ENZYMES

Biochemical Nature:

Enzymes are globular proteins. Like all proteins, they are made up of long, linear chains of amino acids that fold to produce a three-dimensional molecule.

Rates of Reaction:

Most enzyme reaction rates are millions of times faster than those of comparable uncatalyzed reactions. As with all catalysts, enzymes are not consumed by the reactions they catalyze.

Specificity:

Enzymes are usually very specific for the type of reaction and for the nature of their substrates.

Active Site:

Only a small portion of enzyme molecule is directly involved in catalysis. This catalytic region is known as active site. It recognizes and binds substrate and then carries out reaction.

Regulation of Enzyme Activity:

Enzyme production can be enhanced or diminished by a cell according to needs. Enzyme activity can also be regulated by inhibitors and activators.

Need for Co-Factors:

Some enzymes do not need any additional components to work. However, others require some components which are called 'Co-factors'.

Cofactors:

Co-factors are non-protein molecules or ions. Cofactors can be:

- **Inorganic:** e.g. Metal ions
- **Organic:** e.g. Flavin & Heme)

Types of Cofactors:

Cofactors can be of two types:

i. **Prosthetic Groups:**

If the organic cofactors are tightly bound to enzyme, they are called prosthetic groups.

ii. **Co-enzymes:**

If the organic cofactors are loosely attached with enzyme, they are called coenzymes. Coenzymes transport chemical groups from one enzyme to the other.

Some important vitamins act as coenzymes e.g.,

- Riboflavin
- Thiamine
- Folic acid

Regulation of Metabolic Pathways:

Several enzymes can work together in a specific order, creating metabolic pathways. In a metabolic pathway, one enzyme takes the product of another enzyme as a substrate. After the reaction, the product is passed on to the next enzyme.

Q. No. 3 Describe the uses of enzymes.

USES OF ENZYMES

Enzymes are extensively used in different industries for fast chemical reactions. For example:

Food Industry:

Enzymes that break starch into simple sugars are used in the production of:

- White bread
- Buns

Brewing Industry:

Enzymes break starch and proteins. The products are used by yeast for fermentation to produce alcohol.

Paper Industry:

Enzymes break starch to lower its viscosity, which aids in making paper.

Biological Detergent:

- Protease enzymes are used for the removal of protein stains from clothes.
- Amylase enzymes are used in dish washing to remove resistant starch residues.

Q. No. 4 Describe in detail the factors that affect the rate of enzyme action.

FACTORS AFFECTING THE RATE OF ENZYME ACTION

Enzymes are very sensitive to the environment in which they work. Any factor that can change the chemistry or shape of enzyme molecule, can affect its activity. Some of such factors are as follow:

1. Temperature
2. Substrate concentration
3. pH

1. TEMPERATURE

Optimum Temperature:

Every enzyme works at its maximum rate at a specific temperature which is called optimum temperature for that enzyme.

Effect:

Increase in temperature speeds up the rate of enzyme-catalyzed reactions, but only up to a point. When temperature rises to a certain limit, heat adds in the activation energy and also provides kinetic energy for the reaction. So the reactions are accelerated.

Denaturation:

When the temperature is raised well above the optimum temperature, heat energy increases the vibrations of atoms of enzyme and the globular structure of enzyme is lost. This is known as denaturation of enzyme.

Outcome of Denaturation:

Denaturation results in a rapid decrease in rate of enzyme action and it may be blocked completely.

Example:

The optimum temperature for maximum working speed of enzymes in human body is 37°C.

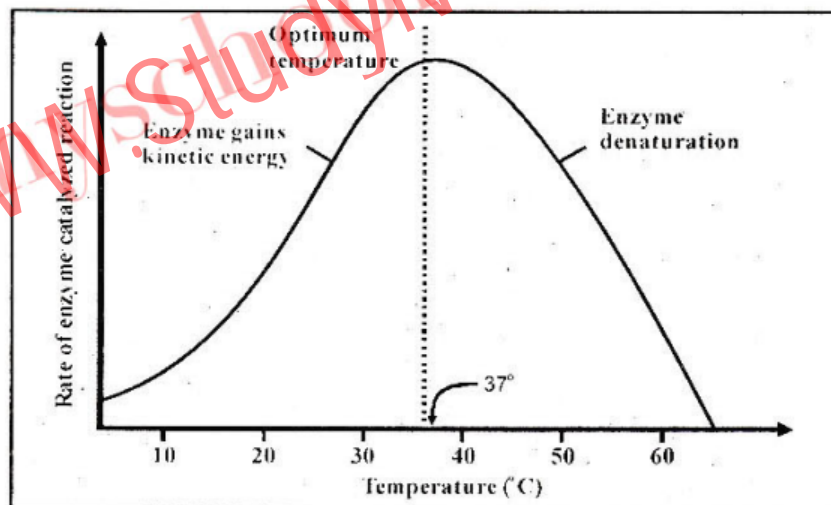



Figure: Effect of Temperature on Enzyme Activity

2. SUBSTRATE CONCENTRATION

Increase in Substrate Concentration:

If enzyme molecules are available in a reaction, increase in the substrate concentration increases the rate of reaction.

Constant Enzyme Concentration:

If enzyme concentration is kept constant, and the amount of substrate is increased, a point is reached where any further increase in the substrate does not increase the rate of reaction any more.

Saturation:

When the active sites of all enzymes are occupied, at high substrate concentrations, any more substrate molecules do not find free active sites. This state is called saturation of active sites and reaction rate does not increase.

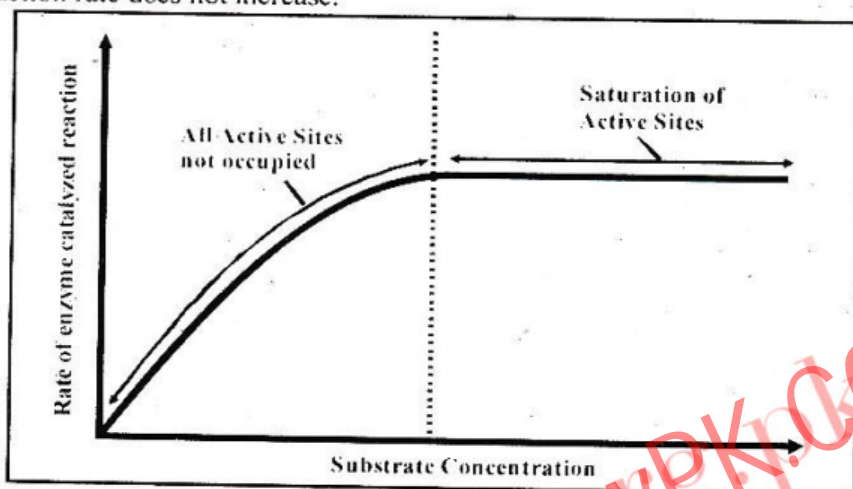



Figure: Effect of Substrate Concentration on Enzyme Activity

3. pH

Optimum pH:

All enzymes work at their maximum rate in a narrow range of pH, called as the optimum pH. Every enzyme has its specific optimum pH value.

Effect of pH Change:

A slight change in optimum pH of an enzyme causes retardation in enzyme activity or blocks it completely. Change in pH can effect the ionization of amino acids at the active site.

Examples:

- Pepsin (working in stomach) is active in acidic medium, i.e. Low pH.
- Trypsin (working in small intestine) shows its activity in alkaline medium i.e. High pH

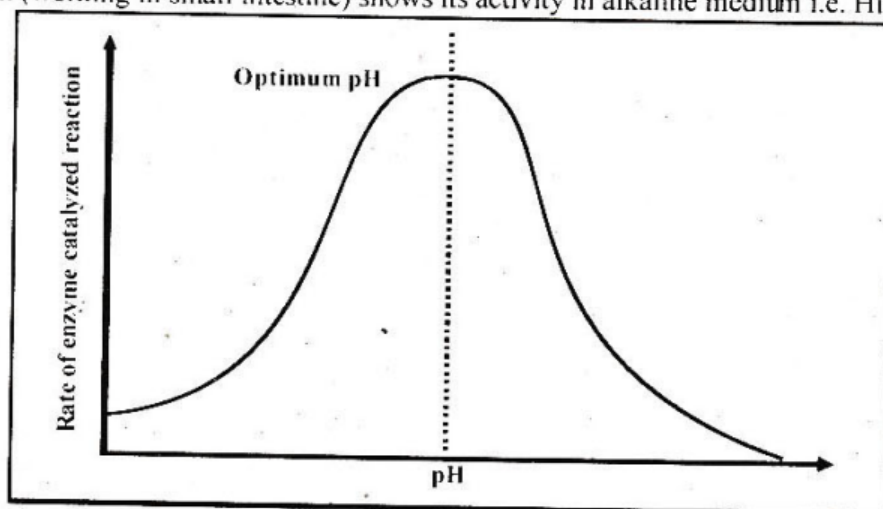
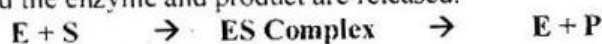



Figure: Effect of pH on Enzyme Activity

Q. No. 5 Describe mechanism of enzyme action.

MECHANISM OF ENZYME ACTION

When enzyme attaches with its substrate, a temporary enzyme-substrate (ES) complex is formed. Enzyme catalyzes the reaction and the substrate is transformed into product. After it, the ES complex breaks, and the enzyme and product are released.

E + S → ES Complex → E + P

LOCK AND KEY MODEL

Presentation:

In order to explain the mechanism of enzyme action, a German chemist Emil Fischer in 1894, proposed 'Lock and Key Model' for enzyme action.

Model:

According to this model:

"Both enzyme and substrate possess specific shapes that fit exactly into one another."

Enzyme Specificity:

This model explains enzyme specificity for its substrates.

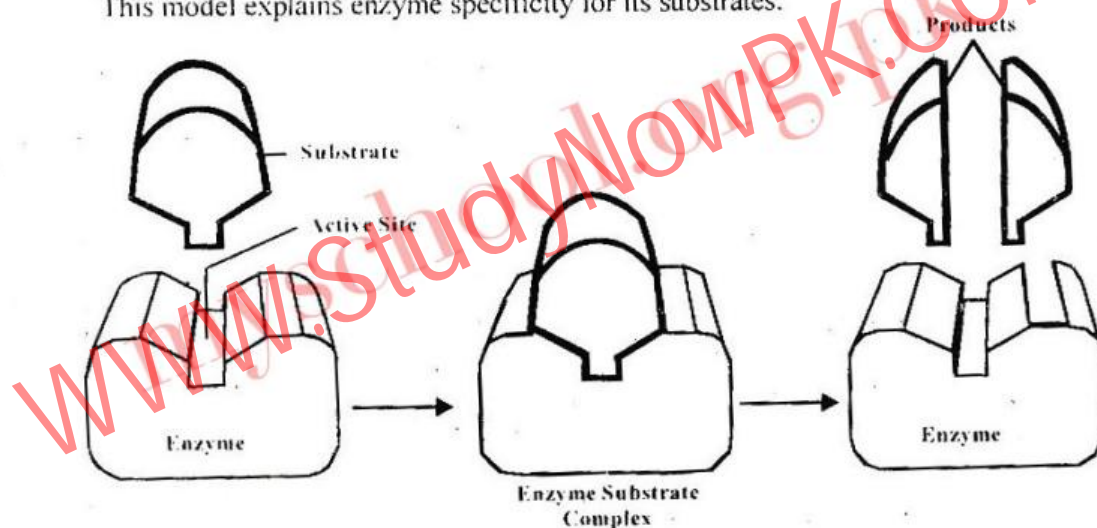



Figure: Lock and Key Model of Enzyme Action

INDUCED-FIT MODEL

Presentation:

In 1958, an American biologist Daniel Koshland suggested a modification to Lock and Key model and proposed 'Induced-fit model'.

Model:

According to this model,

"The active site is not a rigid structure rather it is molded into the required shape to perform its function."

Advantage:

This model is more acceptable than Lock and Key Model.

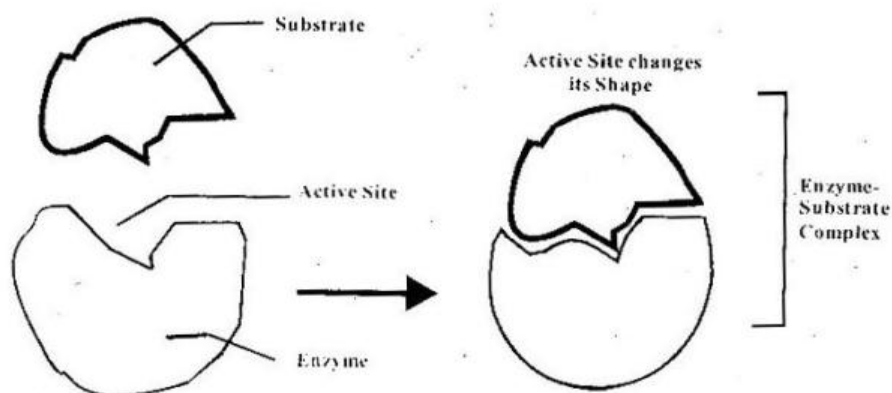



Figure: Induced-Fit Model of Enzyme Action

Q. No. 6 **Explain specificity of enzymes.**

SPECIFICITY OF ENZYMES

Number:

There are over 2000 known enzymes.

Substrate Specificity:

Each enzyme is involved in one specific chemical reaction. Enzymes are also substrate specific.

Determination of Specificity:

Specificity of different enzymes is determined by the shapes of their active sites. Active sites possess specific geometric shapes that fit with specific substrates.

Examples:

- **Protease:** The enzyme protease, which breaks peptide bonds in proteins, will not work on starch.
- **Amylase:** Starch is broken down by amylase.
- **Lipase:** Lipase enzyme acts only on lipids and digests them into fatty acids and glycerol.

Diagrammatic Presentation of Specificity of Enzymes:

In the following diagram, only the substrate 3 will exactly fit in the active site of the enzyme. The substrates 1 and 2 can not fit.

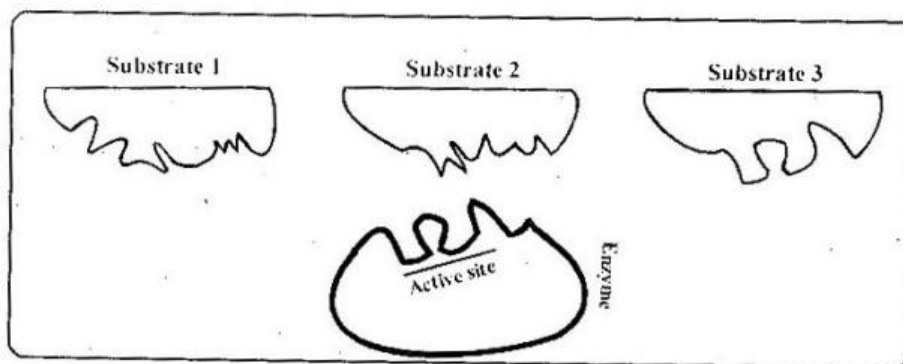
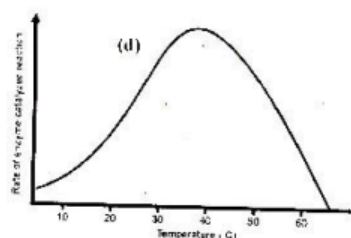
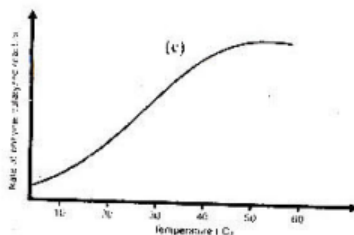
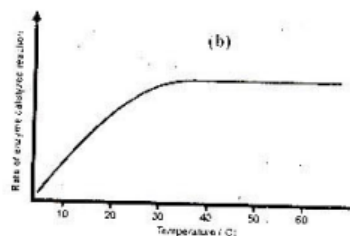
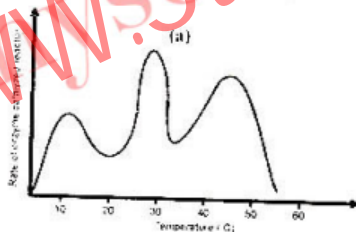



Figure: Specificity of Enzyme due to the Geometric Shape of Active Site

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. **What is true about enzymes?**
   (a) They make biochemical reactions to proceed spontaneously
   (b) They lower the activation energy of a reaction
   (c) They are not very specific in their choice of substrates
   (d) They are needed in large quantities
2. **To what category of molecules do enzymes belong?**
   (a) Carbohydrates (b) Lipids (c) Nucleic acids (d) Proteins
3. **What is true about cofactors?**
   (a) Break hydrogen bonds in proteins (b) Help facilitate enzyme activity
   (c) Increase activation energy (d) Are composed of proteins
4. **Prosthetic groups are:**
   (a) Required by all enzymes (b) Loosely attached with enzyme
   (c) Proteins in nature (d) Tightly bound to enzyme
5. **When we add more substrate to an already occurring enzymatic reaction and there is no increase in the rate of reaction, what would you predict?**
   (a) All active sites have been occupied by substrate molecules
   (b) The enzyme molecules have denatured
   (c) More substrate acted as an inhibitor
   (d) More substrate has disturbed the pH of the medium
6. **Which of these graphs correctly shows the effect of temperature on the rate of enzyme-controlled reaction?**

ANSWERS:

1	b	2	d	3	b	4	d	5	a	6	d

UNDERSTANDING THE CONCEPTS

(1) **How would you define enzymes? Describe their characteristics.**

Consult Short Question No. 12 & Long Question No. 2

(2) **What do you mean by 'Activation Energy' and why is it referred to in the definition of enzymes?**

Consult Long Question No. 1

(3) **In a range of 0-35 °C, the rate of reaction of an enzyme is proportional to temperature. Above 35°C and below 0°C, enzyme activity slows down and eventually stops. Explain why?**

EFFECT OF CHANGE OF TEMPERATURE IN ENZYME ACTIVITY

Temperature is an important factor which affects enzyme activity.

Increase in Temperature:

Increase in temperature speeds up the rate of enzyme-catalyzed reactions, but only up to a point. When temperature increases from 0°C to 35°C, heat adds in the activation energy and also provides kinetic energy for the reaction. So the reactions are accelerated.

Optimum Temperature:

Every enzyme works at its maximum rate at a specific temperature which is called optimum temperature for that enzyme. For this reaction, 35°C is the optimum temperature for the enzyme.

Denaturation:

When the temperature is raised above 35°C, heat energy increases the vibrations of atoms of enzyme and the globular structure of enzyme is lost. This is known as denaturation of enzyme. Denaturation results in a rapid decrease in the rate of enzyme action and it may be blocked completely.

Below 0°C:

Below 0°C, the enzyme does not have sufficient energy to start a reaction so rate of reaction slows down.

(4) **How does pH affect enzyme activity?**

Consult Long Question No. 4

(5) **What characteristics of enzymes make them specific for substrates?**

Enzymes are highly specific for their substrates. This feature can be attributed to special characteristics of enzymes like:

- Active site geometry
- Charge

(6) **Briefly describe the factors that affect the activity of enzymes.**

Consult Long Question No. 4

(7) **Describe the Lock and Key mechanism of enzyme action.**

Consult Long Question No. 5